

**UNCLASSIFIED**

**AD NUMBER**

**AD307752**

**CLASSIFICATION CHANGES**

TO: **unclassified**

FROM: **confidential**

**LIMITATION CHANGES**

TO:

**Approved for public release, distribution  
unlimited**

FROM:

**Distribution authorized to U.S. Gov't.  
agencies and their contractors;  
Administrative/Operational Use; MAY 1959.  
Other requests shall be referred to Dept.  
of the Army, Aberdeen Proving Ground, MD.**

**AUTHORITY**

**APG D/A ltr, 8 Nov 1979; APG D/A ltr, 8  
Nov 1979**

**THIS PAGE IS UNCLASSIFIED**

**UNCLASSIFIED**

**AD 307 752**

**CLASSIFICATION CHANGED  
TO: UNCLASSIFIED  
FROM: CONFIDENTIAL  
AUTHORITY:**

**APG, D/A 4tr. 8 NOV 79**

*Best Available Copy*



**UNCLASSIFIED**

A 307759  
D

# Armed Services Technical Information Agency

ARLINGTON HALL STATION  
ARLINGTON 12 VIRGINIA

FOR  
MICRO-CARD  
CONTROL ONLY

1 OF 2

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA  
ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED  
GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS  
NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE  
GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE  
SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY  
IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER  
PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE,  
USE OR SELL THE SAME IN ANY WAY BE RELATED THERETO.

Best Available Copy

THIS DOCUMENT CONSISTS OF 17 PAGES.  
1 OF 1 COPIES

# Development and Proof Services

AD No. 30775

ASTIA FILE COPY

REFERENCE COPY

Report No. DPS/TW-414/1

FC  
BAC

AUTOMOTIVE DIVISION

REPORT ON INVESTIGATION OF THE RESISTANCE OF  
1-INCH ROLLED HOMOGENEOUS ARMOR PLATE OF  
VARIOUS HARDNESSES TO ANTITANK MINE ATTACK (U)

First Report On Ordnance Project TW-414

(D. A. Project No. 548-03-001)

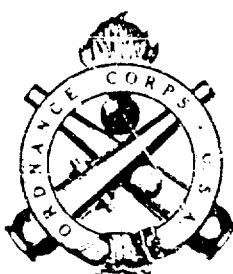
(AD-1267)

17 PAGES

W. V. RESNICK

MAY 1959

Aberdeen Proving Ground  
Maryland



Best Available Copy

**Best  
Available  
Copy**

This document is the property of the United States  
Government. It is furnished for the duration of the contract and  
shall be returned when no longer required. Upon  
recall by ASTIA to the following address:

Armed Services Technical Information Agency, Arlington Hall Station,  
Arlington 12, Virginia

**NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE  
NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING  
OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 AND 794.  
THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN  
ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.**

DEVELOPMENT AND PROOF SERVICES  
ABERDEEN PROVING GROUND  
MARYLAND

ASST. R&D DIV. ORDMC-RM.1

Capt WVRosenick/ch/28264  
7 May 1959

INVESTIGATION OF THE RESISTANCE OF  
1-INCH ROLLED HOMOGENEOUS ARMOR PLATE  
OF VARIOUS HARDNESSES TO ANTITANK MINE ATTACK (U)

First Report on Ordnance Project No. TW-414

Dates of Test: 29 July to 9 September 1958

ABSTRACT (U)

Twenty-three 1-inch-thick rolled homogeneous steel armor plates of various hardnesses having welded crack-starters were tested against 20-pound Composition B-loaded land mines, at a standoff distance of 17 inches. All of the plates were of Army armor except six which had a hardness level of 262 Bhn. These six plates were of STS steel usually designated as Navy armor.

Steel blocks were used as crack-starters and each measured 2 inches square by 3 inches high and was welded centrally on the top surface of the test plates by a single weld pass with a ferritic type electrode. The welds securing the crack-starter blocks were dye-checked to insure against the presence of weld cracking before testing. Each plate was positioned for test on a test facility to simulate mounting as a floor plate in a combat vehicle. All tests were conducted within a temperature range of -40°F and C°F. Damage occurring to each plate was recorded.

"This document contains information concerning the Defense of the United States. It is the property of the Defense Department and is loaned to you; its contents are not to be distributed outside your agency, and its transmission or communication in any manner to an unauthorized person is prohibited by law."

CONTENTS

	<u>PAGE</u>
INTRODUCTION . . . . .	3
DESCRIPTION OF MATERIEL . . . . .	3
DETAILS OF TEST . . . . .	4
Procedure . . . . .	4
Results and Observations . . . . .	5
CONCLUSIONS . . . . .	6
RECOMMENDATIONS . . . . .	6
REFERENCES . . . . .	8
APPENDIX A: LETTER DIRECTIVE . . . . .	A-1
APPENDIX B: SKETCHES OF TEST SETUP . . . . .	B-1
APPENDIX C: PROGRAM FOR TESTING ARMOR PLATE . . . . .	C-1
APPENDIX D: CHARTS OF TEST RESULTS - ONE THROUGH FOUR . . .	D-1
APPENDIX E: PHYSICAL TEST LABORATORY REPORT . . . . .	E-1
APPENDIX F: MANUFACTURER'S CHEMICAL AND PHYSICAL TEST REPORTS . . . . .	F-1
APPENDIX G: PHOTOGRAPHS OF TEST RESULTS . . . . .	G-1
APPENDIX H: DISTRIBUTION . . . . .	H-1

## 1. (U) INTRODUCTION

A number of tests have been conducted in the past to determine the amount of protection provided by cross-rolled homogeneous steel armor plate of 1-inch thickness against antitank mine blast.

This test was conducted to determine the protection provided by 1-inch-thick rolled homogeneous Army armor of various hardnesses, and STS (Navy armor) against land mine blast when the plates are conditioned to low temperatures. It was expected that the results would provide a basis for selecting the best hardness level for rolled steel Army armor floor plates and provide a comparison with STS (Navy armor).

## 2. DESCRIPTION OF MATERIEL

### 2.1 (C) Plate

The plates under test consisted of 1-inch-thick cross-rolled homogeneous steel armor having over-all dimensions of 60 by 84 inches. Six plates were available for testing in each of the hardness levels of 363, 262, and 255 Bhn while only five plates were available at the 302 Bhn hardness level. The physical and chemical properties of the test plates are listed in the manufacturer's test report contained in Appendix F. All plates were Army armor except the six at a hardness level of 262 Bhn. These six plates were STS (Navy armor).

The test plates were numbered consecutively on the upper left hand corner of the photographs, one through twenty-three, inclusive. The plates as referred to in this report will be identified by those numbers instead of using the photograph numbers.

The Brinell hardness and plate identification are as follows:

Armor Type	Brinell Hardness	Plate Number
Homo Rolled (Army)	363	1 through 6
Homo Rolled (Army)	302	7 through 11
Homo Rolled (Army)	255	12 through 17
STS (Navy)	262	18 through 23

### 2.2 (U) Land Mines

The land mines were molded at this installation into cylindrical shape measuring approximately ten inches in diameter by four inches in height with an over-all weight of approximately twenty pounds. The mines were uncased Composition B explosive, Lot No. HOL-7-180.

Also included in the mine was a recess to seat a tetryl pellet.

### 3. DETAILS OF TEST

#### 3.1 (U) Procedure

A steel block measuring 2 inches square by 3 inches high was placed centrally on the top surface of the test plate and fillet-welded by a single pass with a ferritic type electrode around the perimeter of the block (Sketch 1, Appendix B). The fillet welds were then machine-ground to a smooth finish and dye checked to insure against weld cracking.

Two thermocouple leads were welded to the bottom surface of each test plate using silver solder. The thermocouples were located at points approximately eleven inches in from the long edge, thirteen inches in from the short edge and at opposite corners of the test plate (Sketch 2, Appendix B). In addition, two steel rods measuring approximately 1/4 inch in diameter by 3 inches in length and bent into an "S" configuration were also welded at points approximately one inch from the above-mentioned thermocouples. These "S" hooks were placed adjacent to the thermocouples to act as anchors to prevent the thermocouples from breaking off at the weld during final hookup (Sketch 2, Appendix B).

The plates were tested individually in the following manner: a test plate was placed on top of two steel beams measuring approximately twelve inches square by sixty inches in length, with the beams resting on the ground. The distance between the two inside edges of the steel beams was approximately fifty-eight inches. A steel frame weighing approximately three and a half tons was then placed on top of the test plate and squared to insure even coverage.

The frame was then filled with approximately 650 pounds of dry ice. The ice was pulverized by the use of a sledge hammer and spread to give even distribution. It is estimated that approximately 70% of the top surface of the test plate was covered by dry ice.

A tarpaulin 12 feet square was then placed over the entire setup to act as a blanket to assist in lowering the test plate temperature.

The temperature of the test plate was recorded by the use of a constant temperature recording device, connected to the thermocouple leads. For each of the plates tested, plate temperature was lowered 20°F below the actual temperature at detonation time. The 20°F differential was necessary to allow for final preparation before detonation. This preparation consisted of removal of the tarpaulin and dry ice, the placement of the 8-ton hold-down plate centrally on top of the frame, the positioning of the mine beneath the test plate and the final hookup of electrical detonating wires.

A mine was then positioned centrally under the test plate in a predug hole leaving a distance of 17 inches between the top surface of the mine and bottom surface of the test plate. After completion of all necessary safety checks the tetryl pellet and electrical detonating cap were inserted into the mine and the mine was then covered with approximately three inches of loosely packed soil. Upon return of the explosive operator to the bomb-proof, the electrical detonating wires were connected to the detonating machine.

## CONFIDENTIAL

After the temperature of the test slate reached the temperature at which the desired upper fuse time was obtained, detonation of the explosive charge was initiated by electrical detonators and matches. This procedure was followed in the detonation of each slate.

The desired information must be obtained by deformation or separation from the test plates. Young's modulus was taken to show the test results. Graphs, photographs, and G. M. L. prints are included in Appendices I, II, and III.

The twenty-three plates were grouped into four temperature sequences, as outlined by the "Program For Testing," Appendix No. 1, "Test Schedules," Appendix C.

Summarizing the results of the test it may be summarized by saying, shock-starters, application of 300 ft-lbs of the dry ice and the puncturing of the slate was found identical to mean life expectancy for slates of similar thickness.

### 3.2 (1) Results and Observations

The following chart is a plot of Chart No. 1 of values for the test plates and the test conditions and cracking temperature for each separate sample as shown in Figures 1, 2, 3, and 4, Appendix D.

The first group (Chart No. 1 through 6) consists of plates No. 1 through 6 inclusive (Chart No. 1) with a hardness level of 265 HBS and inconsistent performance. Plates Nos. 1 and 2 which were not ruptured at -30° F withstood the mine blast and developed no cracking. Plates Nos. 3, 4, 5, and 6 which were tested respectively at -40°, -30°, -20°, and -10° F all developed extreme failures which included diagonal cracks and sections of the plate material.

The performance of the plates 5, 6, 7, 8, 9, 10, and 11 (Chart No. 2) with a hardness level of 255 HBS was not entirely consistent. Plate No. 7 ruptured at -40° F while plates 5, 6, 8, 9, 10, and 11 which were all tested at -20° F exhibited the same behavior in two cases and developed extreme plate failure in the other two cases. The results are consistent to indicate that -20° F is the critical temperature for failure under mine blast conditions of rolled armor. At temperatures of -10° F or above it might be predicted that no failures would occur but this should be confirmed by actual tests. The performance of test plates Nos. 12, 13, 14, 15, 16, and 17 (Chart No. 3) with a hardness level of 255 HBS was considered to be generally consistent. Plates Nos. 12 and 15 ruptured at a temperature of -30° F. Plates Nos. 13, 14, and 16 which were tested at -20° F gave the same type of failure and one case of extreme rupture. Plate No. 17 (255 HBS at -10° F did not develop any cracking. These results seem to indicate that -20° F as the approximate critical temperature for initial failure on plates of the 255 HBS hardness level.

Test Plates Nos. 18, 19, 20, 21, 22, and 23 (Chart No. 4) consisting of 255 armos with a hardness level of 265 HBS showed better performance in defeating mine blast than all of the other groups of plates reported. All six plates gave very consistent results as related to

CONFIDENTIAL

# **CONFIDENTIAL**

temperature. Plate No. 20 tested at -40°F ruptured but not as severely as some plates in the other groups which were tested at -30°F and -20°F. Plates Nos. 18, 19, 21, and 23 were tested at -30°F with plate No. 18 showing no rupture, plate No. 19 showing only slight cracking, plate No. 21 developing a rupture but not to an extreme degree, and plate No. 23 showing no cracking. Plate No. 22 tested at -20°F did not develop any cracking. These results for the group of STS (Navy armor) plates indicates this is the best material under low temperature conditions to withstand land mine blast.

## **3.3 (U) Charpy Data (Reference PTL Report No. 58-P-40, Appendix E)**

Lower hardness readings were obtained at this installation for the majority of the plates, particularly those of the low hardness groups, than were reported by the armor manufacturer.

The results of the Charpy impact tests performed at APG indicated that the majority of plates met or exceeded specification requirements. Only four plates, Nos. 3, 4, 5, and 6 in the high hardness group, showed Charpy values slightly below the specification requirements.

## **4. (C) CONCLUSIONS**

Based on the results of this test it is concluded that:

- a. Combat vehicle 1-inch rolled steel floor plate material of the STS (Navy armor) type provides better protection when tested at low temperature against the blast from a 20-pound Composition B land mine than rolled homogeneous Army armor at any hardness level from 255 to 363 Bhn.
- b. The performance of the groups of plates tested at low temperatures against mine blast may be ranked as follows:

<u>Numerical Rating</u>	<u>Bhn Hardness</u>
1	262 STS (Navy)
2	302
3	255
4	363

## **5. (C) RECOMMENDATIONS**

Based on the results of this test it is recommended that:

- a. A project be inaugurated to thoroughly investigate the performance of 1-inch STS (Navy armor) at temperature levels from ambient to -40°F against land mine blast to establish definitely whether this material should be selected as a floor plate armor.

<sup>6</sup>  
**CONFIDENTIAL**

**CONFIDENTIAL**

- b. Until STS (Navy armor) has been definitely proven a desirable floor plate material at all service temperatures, Army rolled homogeneous armor in a hardness range of 255 to 302 Bhn be approved for use.

SUBMITTED:

*W.K. Resnick*  
W. K. RESNICK  
Capt, ARMOR  
Proof Officer

REVIEWED:

*W.C. Pless*  
W. C. PLESS  
Chief, Armor Branch

*C.D. Montgomery*  
C. D. MONTGOMERY  
W. A. GROSS, JR  
Chief, Automotive Division

APPROVED:

*H.A. Noble*  
H. A. NOBLE  
Assistant Deputy Director  
for Engineering Testing  
Development and Proof Services

**CONFIDENTIAL**

REFERENCES

Armor Test Report No. AD-1255 and 56th Report on Project TTI-5,  
Titled: Armor Protection Against Land Mines.

APPENDICES

	<u>PAGE</u>
A, LETTER DIRECTIVE . . . . .	A-1
B, SKETCHES OF TEST SETUP . . . . .	B-1
C, PROGRAM FOR TESTING ARMOR PLATE . . . . .	C-1
D, CHARTS OF TEST RESULTS . . . . .	D-1
E, PHYSICAL TEST LABORATORY REPORT . . . . .	E-1
F, MANUFACTURER'S CHEMICAL AND PHYSICAL TEST REPORTS . . .	F-1
G, PHOTOGRAPHS OF TEST RESULTS . . . . .	G-1
H, DISTRIBUTION . . . . .	H-1

COPY/sc

APPENDIX A

Letter Directive

ARMOR BRANCH

ARMOR AND AMMUNITION EFFECTIVENESS DIVISION

DIVISION      TEST PLAN

DATE: 5 Mar 1967  
PLAN NO.: AM-11

PROJECT TITLE:

Armor Protection Against Land Mines

PROJECT ENGINEER: ?

PROJECT NO.: T71-5B/64

OBJECT OF TEST: To obtain information on relative performance of 1" armor of several hardness levels in resisting land mine attack at ambient and sub-zero temperatures.

BACKGROUND: Some testing has been done to obtain the information indicated above. However, variations in test methods & results precluded arriving at definite conclusions. The proposed tests will be performed in a more systematic manner in an effort to obtain the desired information.

ITEMS UNDER TEST:

Six plates 5<sup>1</sup>/<sub>2</sub>"x7<sup>1</sup>/<sub>2</sub>"x1" of each of the following rolled homogeneous armors:

STS armor - BHN 255      Army Armor BHN 255  
Army Armor - BHN 302      Army Armor BHN 362

APPROX. DATES OF TEST: Material not expected      NO. OF ROUNDS: 25-30  
for several months

OUTLINE OF PROGRAM:

1. Place crack starter (welded block 2"x2"x3") in center of each plate
2. Magnaflux welds
3. Test 3 of each type plate at ambient temperature and 3 at -40°F
  - a. Plates will be mounted flat on 2 steel members 12" above ground
  - b. A heavy frame with beveled inner edge will be placed atop the plate and on top of the frame will be placed a heavy hold down plate.
  - c. Mine will be placed 17" below the center of the plate, will be covered with 3" of loosely packed soil and will be statically detonated.
  - d. Amount of plate deformation and cracking, if any, will be recorded.
  - e. Weights of charges will be determined from previous firings and, if necessary, will be adjusted during the course of the test.
4. Formal report will be prepared.

APPROVED: /s/ ROBERT L. ROSENBERG

Chief, Armor & Ammunition Effectiveness  
Division

ORINCO-BM.1

1st Ind

OTAC 476/APG (19 Nov 56)

ORDEBG-LP-TE APG 400.112/5377 (1956)

SUBJ: Armor Protection Against Land Mines

Hq, Ordnance Tank-Automotive Command, Res & Dev Div, Detroit Arsenal  
Center Line, Michigan FEB 18 1957

TO: Commanding General, Aberdeen Proving Ground, Maryland  
ATTN: ORDEBG-LP-TE, Mr. H. M. Cramer Jr.

1. The tests outlined in basic letter are hereby authorized.
2. Funds in the amount of \$10,000 have been issued and PMSD 70405330-11-80022 has been forwarded to Aberdeen Proving Ground to cover the test required. These funds are in the approved project area.
3. This Command will purchase the necessary 24 armor plates (1" x 5' x 7').
4. Distribution of memorandum and final reports should be in accordance with attached distribution lists.

FOR THE COMMANDER:

*C. S. Rasmussen*

C. S. RASMUSSEN  
Assistant

(03)

Incls

w/d Incl 1

Added 2 Incls

2. Memo Rpt Distribution List
3. Final Rpt Distribution List

ORDNANCE CORPS  
ABERDEEN PROVING GROUND

MARYLAND Mr. D. Cressman Jr./TWP/3215  
DEVELOPMENT AND PROOF SERVICES

"REPLY REFER TO  
ORDEC-DP-TE *Copy Ser. No. 5377 (168)*

SUBJECT: Armor Protection Against Land Mines

TO: Commanding General  
Ordnance Tank-Automotive Command  
Detroit Arsenal  
Center Line, Michigan

ATTENTION: ORDTC-RM, 1

- REFERENCES: a. Letter 13 Sep 1955, file APG CMH 476/13, 00/53 20191, Det Ars 476/APG (13 Sep 55) CMH, Subject: First Memorandum Report on Armor Protection Against Land Mines - Expansion of Project TTI-5B (U), with 1st, 2d and 3d endorsements.
- b. Letter 14 July 1955, file APG 400.112/3-248, Det Ars 400.112/APG (14 July 55), Subject: Winter Armor Ballistic Test Program Being Planned for Fort Churchill, Canada 1955-56 (U), with 1st, 2d and 3d endorsements.
- c. Teletype Detroit Arsenal 26 April 1955 TT88385.
- d. Aberdeen Proving Ground Firing Record No. Ar-21392.

1. References a. and d. contain results of tests designed to determine the resistance to cracking and deformation of 1" homogeneous armor (STS-Navy type and Army armor) against land mine attack at ambient and sub-zero temperatures. A review of the results reported therein indicates the need for considerable additional firing to more definitely establish the relative performance of the two types of material and the optimum hardness of material for tank floor plates. In short, so many variables in test procedures were employed in an effort to arrive at the most reproducible test method, and results were consequently of such a variable nature, that definite conclusions cannot be drawn from these data.

2. Through trial and error it has been established that the most satisfactory method of mounting the items for test is as shown in sketch 1, inclosure 1, and described below:

- a. A 2" square x 3" high steel block is placed centrally on the top surface of the 5' x 7' test plate and is fillet welded (1/4" austenitic electrode) by a single pass around the perimeter of the block.

C 1.9.3

ORDDG-DP-TE

SUBJECT: Armor Protection Against Land Mines

b. The test plate is set in an horizontal position with its two 7' sides resting on and extending 2" over 1" x 1" x 7' steel supports placed on the ground. Distance between the two steel supports is 56 inches.

c. A steel frame 8" thick, to provide for maximum plate deformation, and an 8-ton hold-down plate are placed atop the test plate.

d. The mine is emplaced beneath the center of the test plate at a distance of 17" from top of mine to the bottom surface of the plate, and the mine is covered with three inches of loose soil and is statically detonated.

3. Much of the current testing to determine the mine explosive weight required to defeat Army armor of specification hardness and of various thicknesses from 1/4" through 1-1/2" has been carried out using the method just described and results, for the most part, are consistent for given explosive weight/armor thickness combinations.

4. It is recommended that tests previously carried out in an effort to compare STS and Army armor and to compare different hardnesses of Army armor be repeated using the improved technique described above and employing a mine explosive weight to be determined from the tests referred to in paragraph 3. It is the opinion that at least 3, and preferably 5, trials should be conducted for each combination of plate type/plate hardness/and test temperature. For such a program the following material would be required:

<u>Plate Size</u>	<u>Type Armor</u>	<u>Hardness</u>	<u>Test Temperature</u>	<u>Number of Plates</u>	
				<u>Minimum</u>	<u>Desired</u>
1" x 5" x 7"	STS	255	Ambient	3	5
1" x 5" x 7"	STS	255	Sub-zero	3	5
1" x 5" x 7"	Army RH	255	Ambient	3	5
1" x 5" x 7"	Army RH	255	Sub-zero	3	5
1" x 5" x 7"	Army RF	302	Ambient	3	5
1" x 5" x 7"	Army RF	302	Sub-zero	3	5
1" x 5" x 7"	Army RR	342	Ambient	3	5
1" x 5" x 7"	Army RR	342	Sub-zero	3	5

CRDSEC-DR-93

SUBJECT: Armor Protection Against Land Mines

5. It is estimated that the cost of testing the above plates would be \$10,000 for the minimum sample size and \$16,000 for the desired sample size. Comments at an early date would be appreciated.

*Colleran*

T. F. COLLERAN  
Director

1 Incl  
1. Sketch

(8)

NSpire/pv/24-106

ORDMC-RM.1

17 February 1958

SUBJECT: Test Directive for Mine Test Program  
for 1" Rolled Armor

TO: Commanding General  
Aberdeen Proving Ground  
Aberdeen, Maryland  
ATTENTION: Mr. W. C. Pless

REFERENCE: a. PASD 70405330-11-80022 dtd 30 Jan 57  
b. Ltr File No. APG 400.112/5377 dtd 19 Nov 56

1. Twenty-four (24) plates of 1" rolled armor plate of various hardness are to be shipped to Aberdeen Proving Ground from Lukens Steel Company by 1 March 1958.

2. The funding for testing the armor plates is covered by reference "a".

3. The original test program, reference "b", is to be revised slightly as noted below:

a. Type of mine: 20# (comp B).

b. Crack Starter: welds should be ground and then checked for cracks.

c. Method of Testing: See attached sketch for Plates 1 through 4. Plates 5 and 6 are to be used as check plates.

4. This office desires to be notified in advance of scheduled firings to permit attendance by interested personnel.

FOR THE COMMANDER:

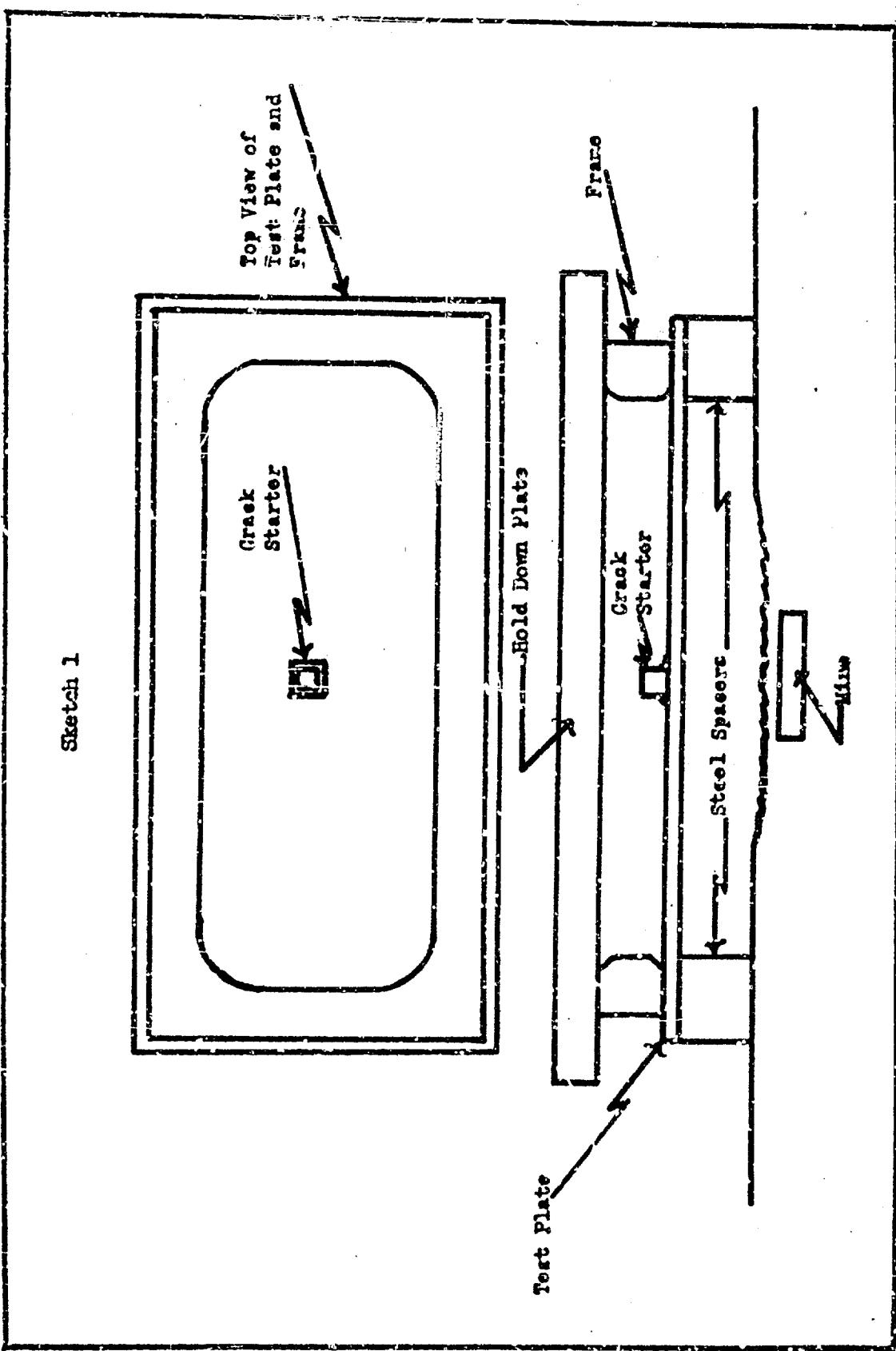
1 Jack  
Sketch of Method  
of Testing (in dupe)

W. D. ENGLAND  
Chief, Materials Branch

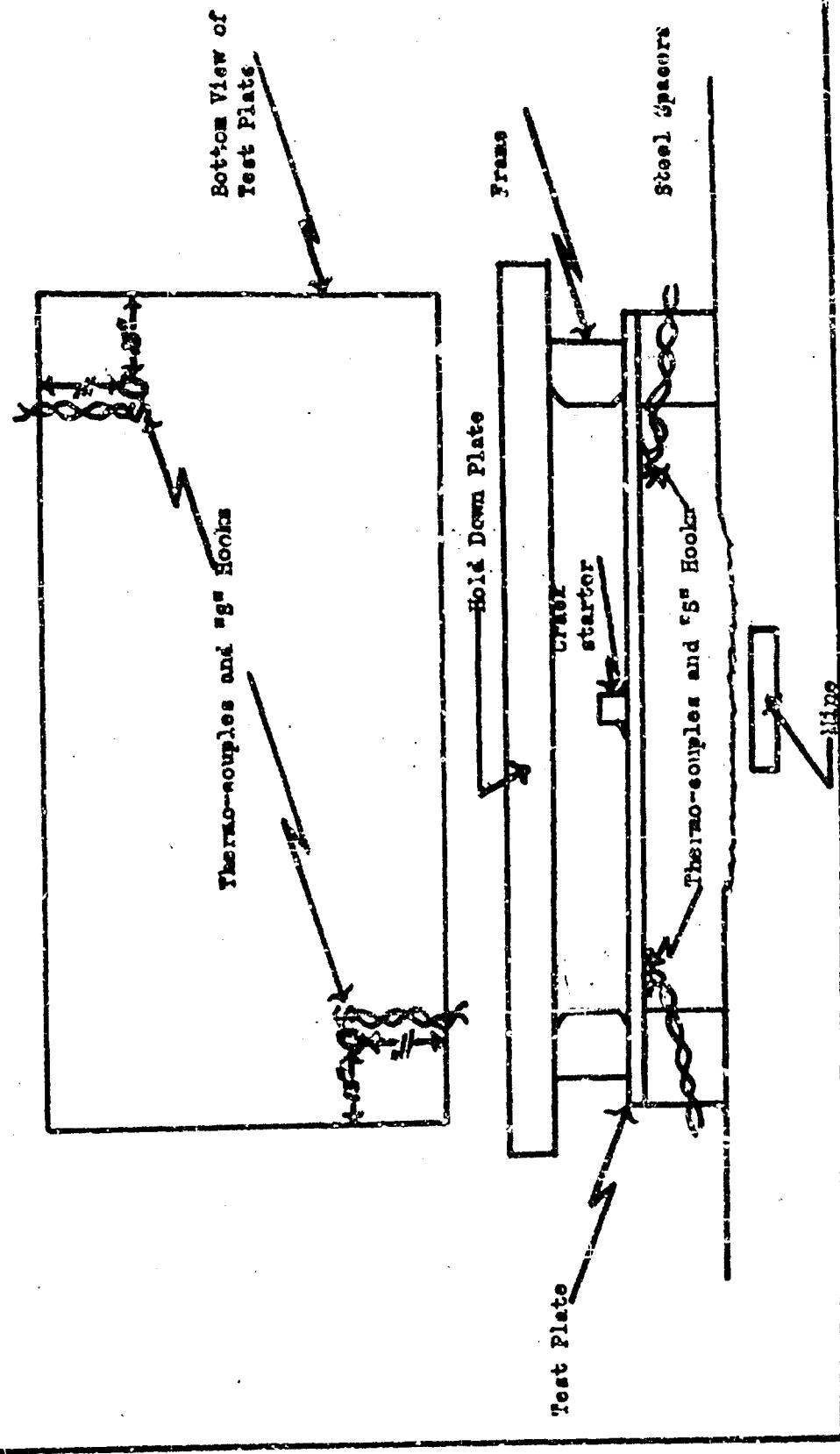
APPENDIX E

Sketches of Test Setup

Sketch 1



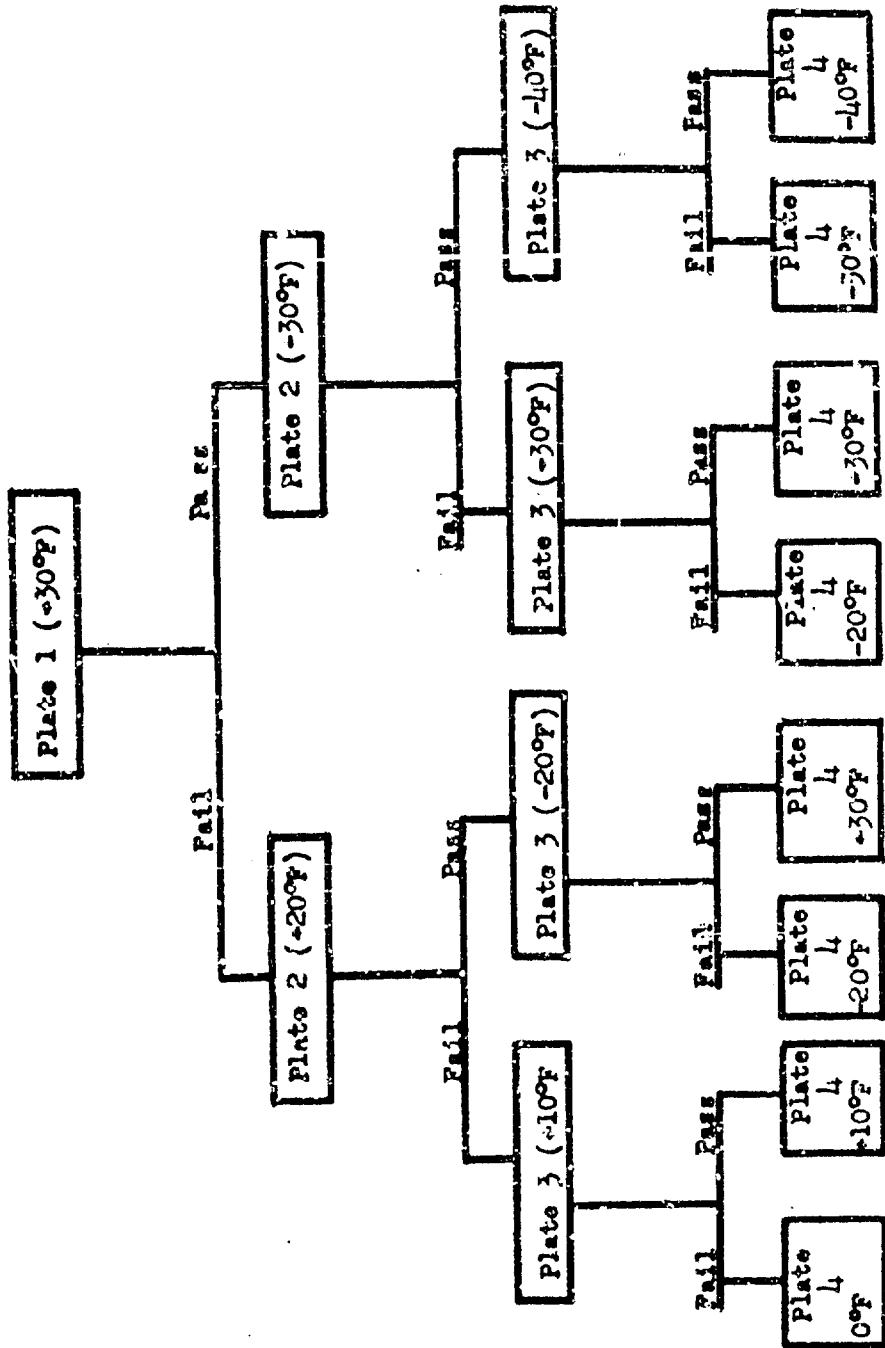
Sketch 2



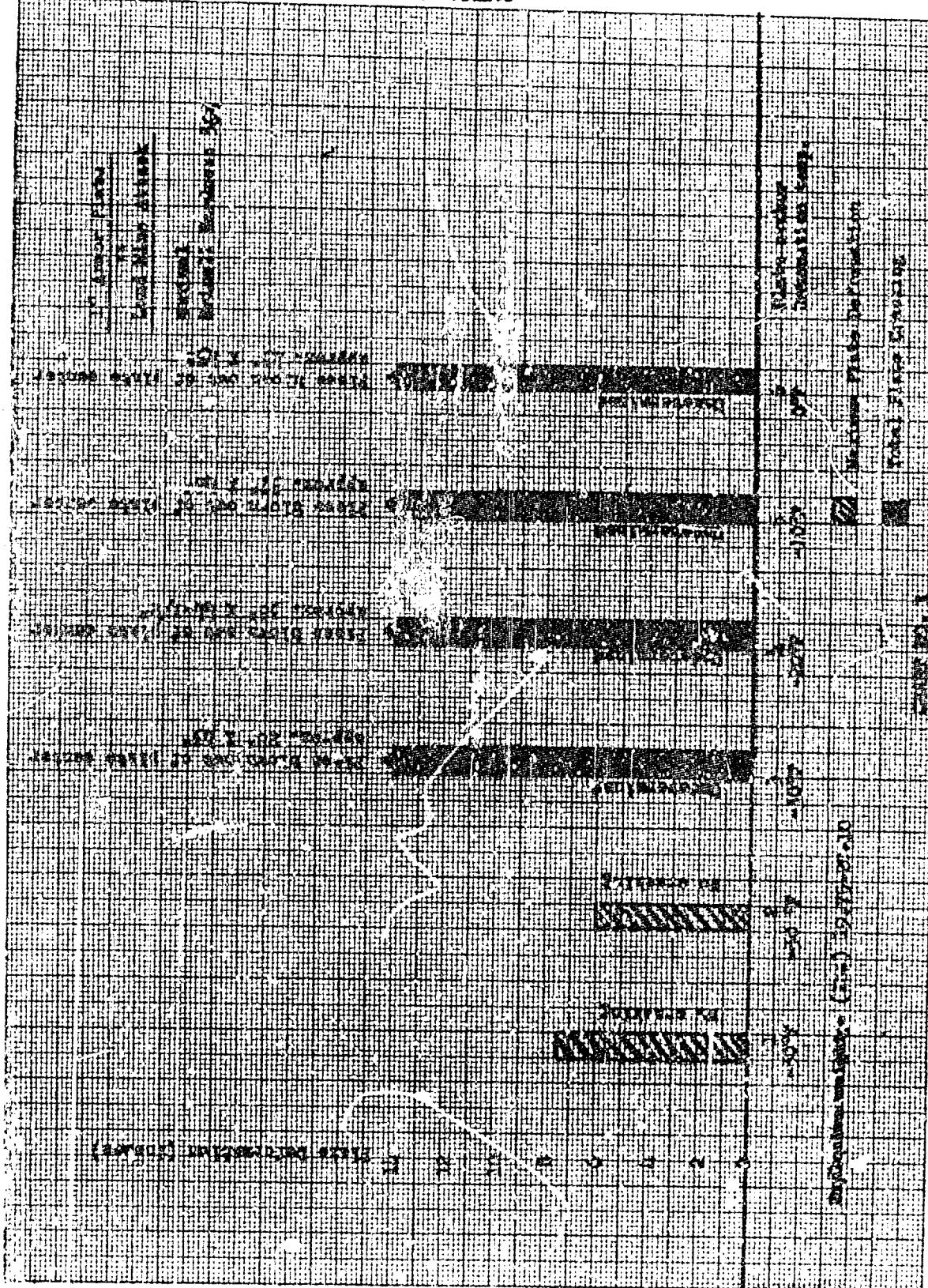
PROGRAM FOR TESTING ARMOR PLATE MATERIAL WITH NAMES

APPENDIX C

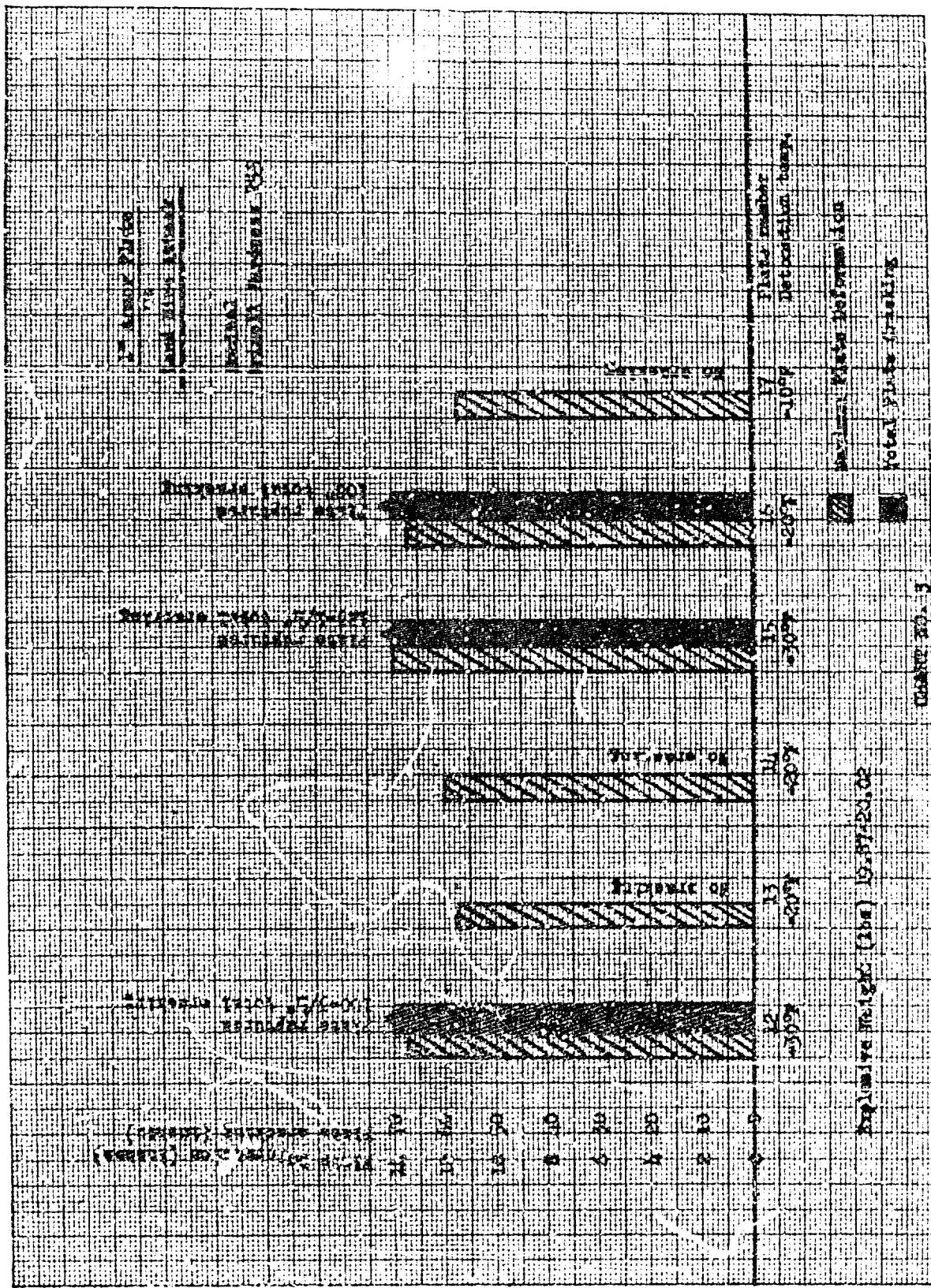
Program for Testing Armor Plate

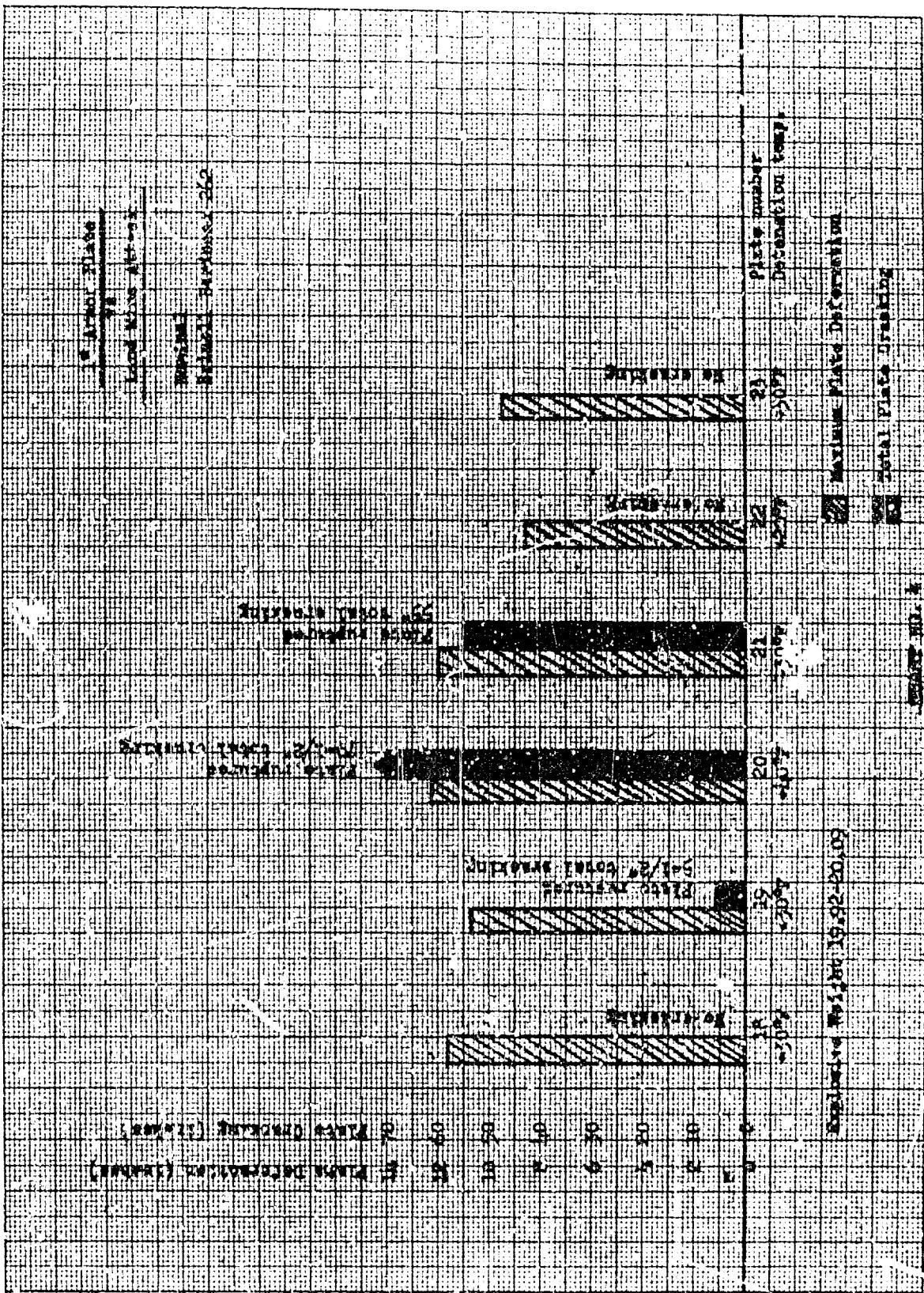


**APPENDIX D**  
**Charts of Test Results**









APPENDIX E  
Physical Test Laboratory Report

ENGINEERING LABORATORIES  
PHYSICAL TEST LABORATORY REPORT

ORDBG-DP-LP

EXAMINATION OF:

Twenty-three Samples of  
1" Wrought Armor.

OBJECT OF EXAMINATION:

To obtain Brinell Hardness  
and Charpy Impact Data on the  
plates.

EXAMINATION PROCEDURE:

1. 4" square plates were  
sawed from flame cut samples  
and supplied to the laboratory  
for determination of the major  
working direction.

2. The test samples were macroetched for one hour in 50% HCL. The  
major working direction was indicated and the samples were returned to  
the machine shop for machining standard Charpy "V" notch specimens, one  
specimen from each sample.

3. Charpy specimens were cooled to -40° F for 30 minutes, and broken  
on the impact testing machine. Fracture ratings were made on the specimen  
fracture surfaces.

4. Brinell hardness readings were taken on the broken Charpy specimens.

RESULTS:

Tabulated results follows:

Spec. No.	Energy, ft-lbs.	Fracture, % Shear	BHN*	Spec. Charpy Energy, ft-lbs.
1	22.5	25	352-	16.7
2	17	25	363	15.0
3	15.5	25	352-	16.7
4	14.5	25	363	15.0
5	16.5	25	352-	16.7
6	14	25	363	15.0
7	36.5	100	311+	25.4
8	40	100	311+	25.4

<u>Spec. No.</u>	<u>Energy, ft-lbs.</u>	<u>Fracture, % Shear</u>	<u>BHN*</u>	<u>Spec. Charpy Energy, ft-lbs.</u>
9	39.5	100	302	28.0
10	46	100	277	38.4
11	38.5	100	311	25.4
12	64.5	85	217	53.5 **
13	53.5	100	217	53.5 **
14	54.5	100	229	48.0 **
15	60.5	100	229	48.0 **
16	58	100	223	50.7 **
17	58.5	100	223	50.7 **
18	64.5	100	241	43.0 **
19	78.5	100	255	37.0 **
20	76	100	248	40.0 **
21	80	100	241	43.0 **
22	74.5	100	241	43.0 **
23	84	100	241	43.0 **

\* Specified BHN for 1" plate is 331-375.

\*\* Hardness values are outside range given for plate up to 4", so Charpy values are applicable to plate 4"-12" only.

#### SUMMARY OF RESULTS:

1. Plates 1-6 met the specification hardness requirement. Plates 1-2 and 7-23 met the specification impact requirement. Only plates 1 and 2 met both hardness and impact requirements.

SUBMITTED:

R. L. Huddleston  
R. L. HUDDLESTON  
Chief,  
Radiographic & Metallurgical Section

APPROVED:

J. M. McKinley  
J. M. MCKINLEY  
Chief,  
Physical Test Laboratory

Form ODRX-1 3983  
21 Dec 49APPENDIX F  
Manufacturer's Chemical and Physical Test Reports  
ARMOR DATA CHECK SHEET  
SIP-12ORDNANCE DEPARTMENT  
DETROIT ARSENAL

MFG. RECORD NO.		PRIMARY CONTRACTOR		FIRING RECORD NO.							
MFG. LUKENS STEEL COMPANY ADDRESS COATESVILLE, PA. MFG. DATE 10/27/57 SHIPPED TO ABERDEEN PROV. ORDS. SHIPPED VIA: FRT EXP TRK X PURPOSE: ACC QUAL DEV X SAMPLE: PRIMARY RETEST CASTING REPRESENTS: 9,000 LBS. CASTING NO,		PHILA. ORD. DISTRICT 128 N. BROAD ST. PHILADELPHIA 2, PA. CONTRACT DA-36-034-ORD-2525RD FILE# 2525 R.D. ORDNANCE DISTRICT (OR ARSENAL) PHILA. ORD. DISTRICT		FIRING DATE SPECIFICATION MIL-A-12560 REVISION AMENDMENT TYPE ARMOR: HOMO X, FH CAST ROLLED FORGED FURNACE: OH X ELECT. BASIC ACID STEEL SOURCE LUKENS STEEL CO MATERIAL FOR USE ON RESEARCH & DEVELOPMENT							
CHEMICAL COMPOSITION				STEEL MILL FRACTURE DATA							
C	Mn	Si	S	P	Cr	Ni	Mo	LOCATION	1ST INGOT	MID. INGOT	LSD. INGOT
1.26	1.69	24	0.22	0.16	0.08	29	47	TOP	A-	A-	A-
2								MIDDLE	A-	A-	A-
3								BOTTOM	A-	A-	A-
HEAT TREATMENT											
CARBURIZE	HOMOGENIZE			NORMALIZE			HARDEN			DRAW	
	TEMP	TIME	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	COOLANT
1							1650°F.	2 HRS.	950°F.	2 HRS.	WATER
2											
HEAT NO.	INGOT	SLAB	PLATE NO.	THICK	SIZE	REQ. BHN	ACTUAL BHN		HEAT TREATED FRACTURE		
LL22104						331/375					
2						962					
3											
PHYSICAL PROPERTIES								RADIOGRAPHIC INSPECTION			
CHARPY	BHN	IMPACTS			ELON S 2"	RA %	STANDARD	PASSED OR FAILED			
TEMP FT LBS	XXX	XXX	XXX	XXX							
1 -40°F.	352	AVG	19.5	AVG.							
2	352/352	17.5-18.5									
3	341	AVG	17.5	AVG.	"	"					
REMARKS 3 PLATES SHIPPED ON MELT LL22104 1-1 SIZE-84 X 60 X 1" BHN RANGE 351/375 1/3 PLATES SHIPPED ON MELT LL22104 2-3 SIZE-84 X 60 X 1" BHN RANGE 364/364 H.A. GRIND H.A. Grind by L. T. Tontz BLANK LUKENS STEEL CO.											
BALLISTIC TEST RECORD											
TEST	PROJECTILE	OBL.	THK.	REQD. VEL.	ACT. VEL.	RESULT	REMARKS				
1											
2											
3											
PROOF FACILITY SIGNATURES											

FORM ORDN-1  
21 Dec 49 3963ARMOR DATA CHECK SHEET  
SIP-12ORDNANCE DEPARTMENT  
DETROIT ARSENAL

MFG. RECORD NO.		FIRING RECORD NO.	
MFG. LUKENS STEEL COMPANY		PRIMARY CONTRACTOR	
ADDRESS COATESVILLE, PA.		PHILA. ORD. DISTRICT	
MFG. DATE 10/27/57		128 N. BROAD ST.	
SHIPPED TO ABERDEEN PROV. GRDS.		PHILADELPHIA 2, PA.	
SHIPPED VIA: FRE EXP TRK X		CONTRACT	
PURPOSE: ACC QUA <sup>L</sup> DEV X		DA-36-034-ORD-2525RD	
SAMPLE: PRIMARY RETEST CASTING		FILE# 2525 R.D.	
REPRESENTS: 9,000 LBS.		ORDNANCE DISTRICT (CR ARSENAL)	
CASTING NO.		PHILA. ORD. DISTRICT	

CHEMICAL COMPOSITION									STEEL MILL FRACTURE DATA			
C	Mn	Si	S	P	Cr	Ni	Mo		LOCATION	1ST INGOT	MID. INGOT	LAST INGOT
1.26	1.51	24	022	016	08	21	47		TOP	A-	A-	A-
2									MIDDLE	A-	A-	A-
3									BOTTOM	A-	A-	A-

HEAT TREATMENT									
CARBURIZE TEMP TIME	HOMOGENIZE		NORMALIZE		HARDEN		DRAW		COOLANT
	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	
1					1450°F.	2 HRS.	1050°F.	2 HRS.	WATER
2									
3									
HEAT NO.	INGOT	SLAB	PLATE NO.	THICK	SIZE	REQ BHN	ACTUAL BHN	HEAT TREATED FRACTURE	
1 LL22104						293/321			
2							302		
3									

PHYSICAL PROPERTIES							RADIOGRAPHIC INSPECTION	
CHARPY	BHN	IMPACTS	TEMP FT LBS	XXXXXX	ELON 5 2"	RA 5	STANDARD	PASSED OR FAILED
1 -40°F.	302	59.0-35.0						
2 -40°F.	302	59.5-36.0						
3 -40°F.	302	40.0-40.0						

REMARKS / PLATES SHIPPED ON MELT LL22104 1-2 SIZE-84 X 60 X 1" BHN RANGE 321/321  
✓2 PLATES SHIPPED ON MELT LL22104 1-3 SIZE 84 X 60 X 1" BHN RANGE 293/321  
H.A. GRUBB *Half hard treat*  
PET. ENGR. PLANT LUKENS STEEL CO.

BALLISTIC TEST RECORD							
TEST	PROJECTILE	VEL.	INCH.	REQD. VEL.	ACT. VEL.	RESULT	REMARKS
1							
2							
3							

PROOF FACILITY SIGNATURES

Form ORDNX-1 3983  
21 Dec 49

ARMOR DATA CHECK SHEET  
SIP-12

ORDNANCE DEPARTMENT  
DETROIT ARSENAL

MFG. RECORD NO.  
**MFG. LUKENS STEEL COMPANY**  
ADDRESS COATESVILLE, PA.  
MFG. DATE 10/27/57  
SHIPPED TO ABERDEEN PROV. GRDS.  
SHIPPED VIA: FRT EXP TRK X  
PURPOSE: ACC QUAL DEV X  
SAMPLE: PRIMARY RETEST CASTING  
REPRESENTS: 9,000 LBS.  
CASTING NO.

PRIMARY CONTRACTOR  
PHILA. ORD. DISTRICT  
128 N. BROAD ST.  
PHILADELPHIA 2, PA.  
CONTRACT  
DA-36-034-ORD-2525RD  
FILE# 2525 R.D.  
ORDNANCE DISTRICT  
(OR ARSENAL)  
PHILA. ORD. DISTRICT

FIRING RECORD NO.  
FIRING DATE  
SPECIFICATION M3L-A-12560  
REVISION AMENDMENT  
TYPE ARMOR: HOMO<sup>X</sup> FH  
CAST ROLLED FORGED  
FURNACE: OH X ELECT.  
BASIC ACID  
STEEL SOURCE LUKENS STEEL CO.  
MATERIAL FOR USE ON  
RESEARCH & DEVELOPMENT

CHEMICAL COMPOSITION

C	Mn	Si	S	P	Cr	Ni	No	LOCATION	1ST INGOT	MID. INGOT	LAST INGOT
1.26	1.61	24	0.22	0.16	0.08	21	47	TOP	A-	A-	A-
2								MIDDLE	A-	A-	A-
3								BOTTOM	A-	A-	A-

HEAT TREATMENT

CARBURIZE TEMP TIME	HOMOGENIZE		NORMALIZE		HARDEN		DRAW		COOLANT
	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	TEMP	TIME AT TEMP	
1					1650°F.	2 HRS.	1175°F.	2 HRS.	WATER
2									

HEAT NO.	INGOT	SLAB	PLATE NO.	THICK	SIZE	REQ BHN	ACTUAL BHN	HEAT TREATED FRACTURE
1 LL 22104						241/269		
2						241		
3								

PHYSICAL PROPERTIES

CHARPY TEMP FT LOC	BHN	IMPACTS	ELON S 2"	RA S	STAB. ABS	PASSED OR FAILED
1 -40°F,	241	60.0-59.5				
2	241	60.0-62.0				
3	241	62.0-59.0				

REMARKS 3 PLATES SHIPPED ON MELT LL22104 2-2 SIZE 84 X 60 X 1" BHN RANGE 255/255  
3 PLATES SHIPPED ON MELT LL22104 2-1 SIZE 84 X 60 X 1" BHN RANGE 241/255

H.A. GRUBB 7/6. Hubbell, L. T. T.  
ENGR. PLANT LUKENS STEEL CO.

BALLISTIC TEST RECORD

TEST	PROJECTILE	OBL.	TICKS.	REQD. VEL.	ACT. VEL.	RESULT	REMARKS
1							
2							
3							

PROOF FACILITY SIGNATURES

PHILADELPHIA ORD. DISTRICT  
128 N. BROAD ST.  
PHILADELPHIA 2, PA.

FORM NO. 221

PS

LUKENS STEEL COMPANY  
COATESVILLE, PA.

TEST REPORT  
AFFI

TO : ABERDEEN PROVING GRS.  
: ABERDEEN, MD.  
: ATT: COMMANDING GENERAL  
: ORDBO-DT-TT/MR. W. C. PLESS

CHEMICAL ANALYSIS

MELT NO.	SLAB NO.	C	MN	P	S	CU	Si	Ni	CR	Mo	YIELD P.S.I.	TENSILE P.S.I.	% ELONGATION IN 2 IN.	% BHN	SIZE OF PLATE
19026	38	.26	.22	.014	.026		25	3.22	1.30		104000	122500	23	66.0	262
											102000	121700	24	66.7	262

262

F-4

PLATES AND TESTS QUENCHED AND TEMPERED.  
ABOVE PLATES HAVE MET BALLISTIC REQUIREMENT OR SPECIFICATION.  
THE ABOVE TESTS WITNESSED BY USN INSPECTOR.

13

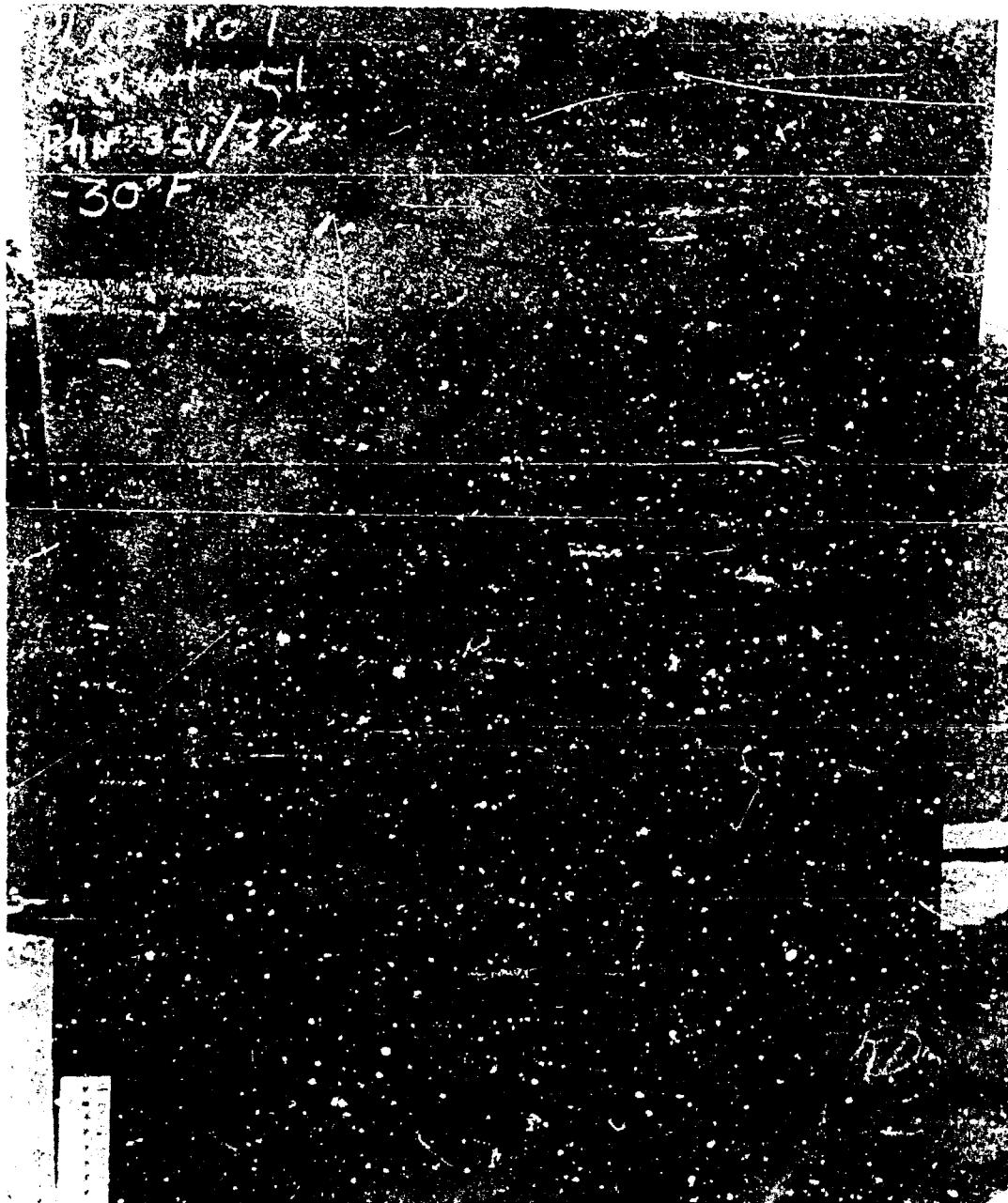
APR-17 1955

I HEREBY CERTIFY THAT THE ABOVE TESTS ARE CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

LUKENS STEEL COMPANY

ASST ENGR OF TESTS

**CONFIDENTIAL**



B31891: Plate No. 1, HEAT No. LL-22104 1-1, Bhn Range 351/375. Front View. Detonated at -30°F.

G-1

**CONFIDENTIAL**

**CONFIDENTIAL**

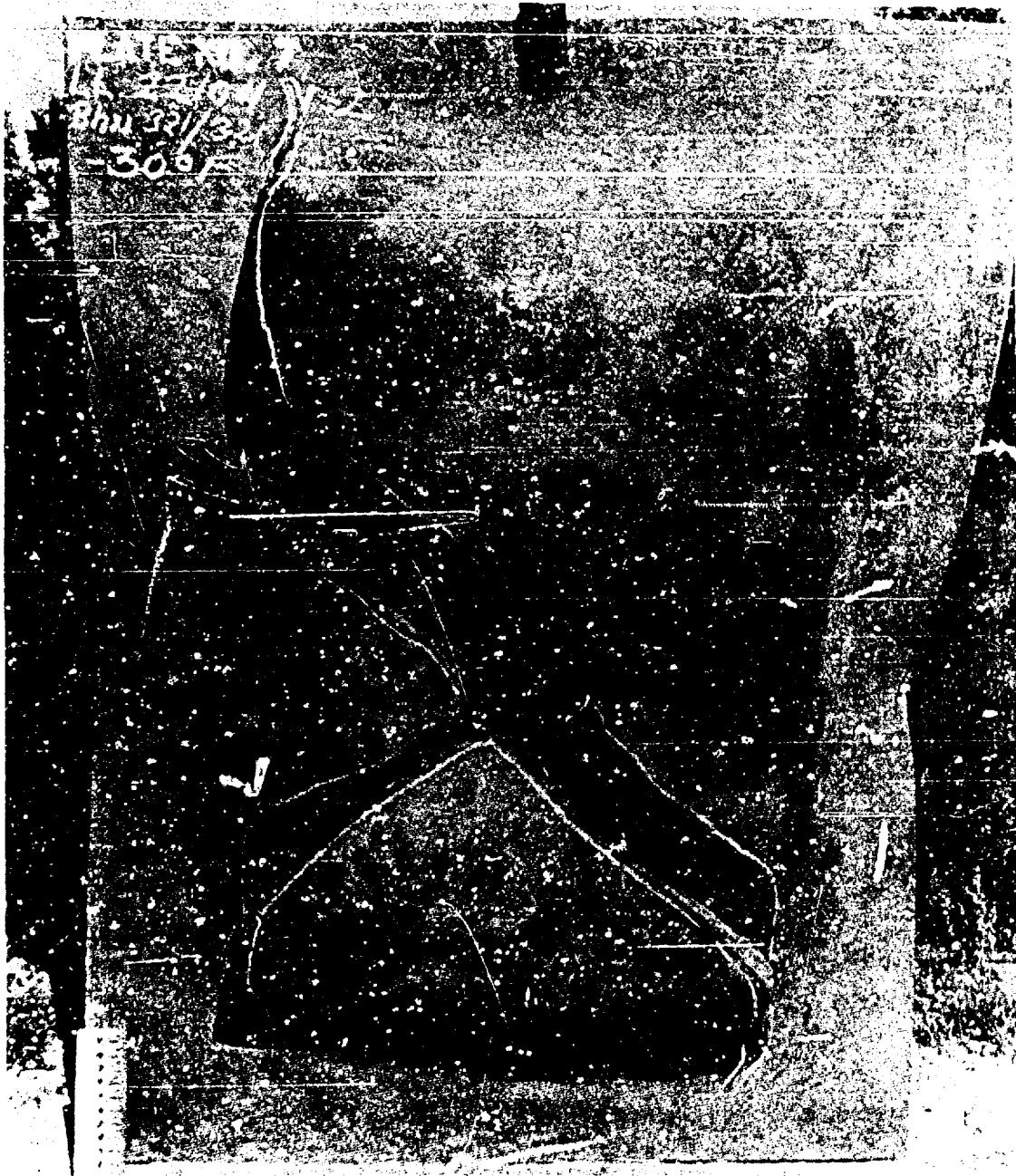


B31890: Plate No. 1, HEAT No. II-22104 1-1, Ehn Range 351/375. Rear View. Detonated at -30°F.

G-2

**CONFIDENTIAL**

**CONFIDENTIAL**



131892: Plate No. 7, HEAT No. LL-22104 1-2, Bhn Range 321/321. Front View. Detonated at -30°F.

**CONFIDENTIAL**



B31893: Plate No. 7, HEAT No. 22104 1-2, Elm Range 321/321. Rear View. Detonated at -30°F.

G-4

**CONFIDENTIAL**

**CONFIDENTIAL**



B31894: Plate No. 8, HEAT No. LL-22104 1-2, Ehn Range 321/321. Rear View. Detonated at -20°F.

G-5

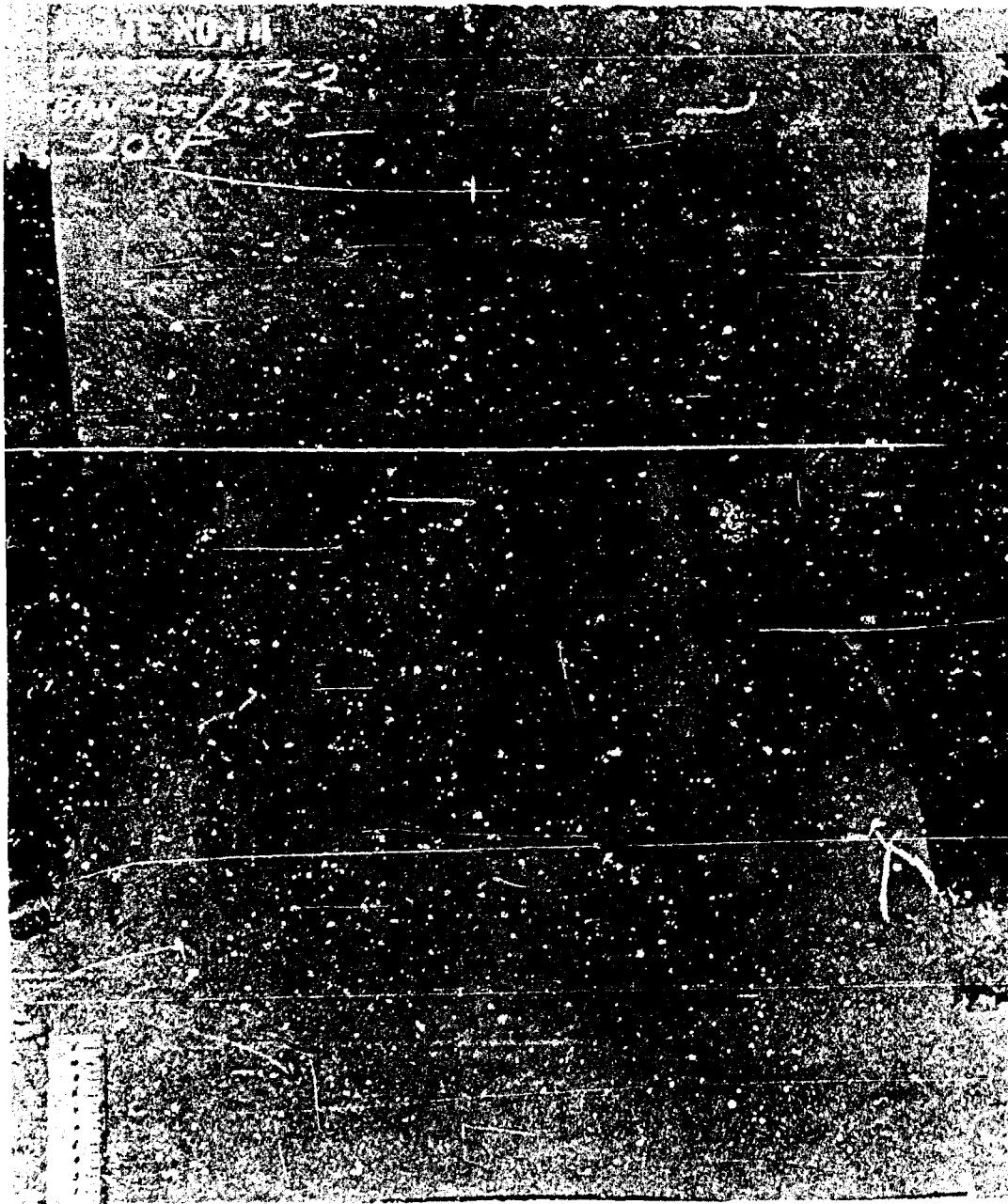
**CONFIDENTIAL**

**CONFIDENTIAL**



B31895: Plate No. 8, HEAT No. 22104 1-2, Ehn Range 321/321. Front View. Detonated at -20°F.

**CONFIDENTIAL**



B31896: Plate No. 14, HEAT No. LL-22104 2-2, Ehn Range 255/255. Rear View. Detonated at -20°F.

**CONFIDENTIAL**

**CONFIDENTIAL**



B61897: Plate No. 14, HEAT No. LL-22104 2-2, Bin Range 255/255. Front View. Detonated at -20°F.

G-8

**CONFIDENTIAL**

**CONFIDENTIAL**



B31898: Plate No. 15, HEAT No. LL-22104 2-1, Bln Range 241/255. Front View. Detonated at -30°F.

G-9  
**CONFIDENTIAL**

**CONFIDENTIAL**



B31899: Plate No. 19, HEAT No. 19026 3-P, Bhn Range 262. Front View.  
Detonated at -30°F.

G-10

**CONFIDENTIAL**

**CONFIDENTIAL**



B31900. Plate No. 19, HEAT No. 19026 3-B, Bhn Range 262. Rear View.  
Detonated at -30°F.

**CONFIDENTIAL**

**CONFIDENTIAL**



B31001: Plate No. 21, HEAT No. 19026 3-B, Bhn Range 262. Rear View.  
Detonated at ~40°F.

C-12

**CONFIDENTIAL**

**CONFIDENTIAL**



B31902: Plate No. 21, HEAT No. 19026 3-B, Rhn Range 262. Front View.  
Detonated at -30°F.

G-13

**CONFIDENTIAL**

**CONFIDENTIAL**



B31903: Plate No. 16, HEAT No. LL-22104 2-1, Bhn Range 241/255. Front View. Detonated at -20°F.

G-14

**CONFIDENTIAL**

**CONFIDENTIAL**



B31904: Plate No. 16, HEAT No. LL-22104 2-1, Ehn Range 241/255. Rear View. Detonated at -20°F.

G-15

**CONFIDENTIAL**

**CONFIDENTIAL**



P31905: Plate No. 17, HEAT No. LL-22104 2-1, Bhn Range 241/255. Rear View. Detonated at -10°F

G-15

**CONFIDENTIAL**

**CONFIDENTIAL**



B31906: Plate No. 17, HEAT No. LL-22104 2-1, Ehn Range 241/255. Front View. Detonated at -10°F.

**CONFIDENTIAL**



B31907: Plate No. 11, HEAT No. LL-22104 1-2, Bhn Range 321/321. Front View. Detonated at -20°F.

G-16

**CONFIDENTIAL**

**CONFIDENTIAL**



B31908: Plate No. 5, HEAT No. LL-22104 1-1, Ehn Range 351/375. Front View. Detonated at -10°F.

G-10

**CONFIDENTIAL**

**CONFIDENTIAL**



B31909: Plate No. 9, HEAT No. LL-22104 1-3, Ehn Range 293/321. Front View. Detonated at -20°F.

G-10

**CONFIDENTIAL**

**CONFIDENTIAL**



B31910: Plate No. 3, HEAT No. LL-22104 1-1, Bhn Range 351/375. Front View. Detonated at -30°F.

**CONFIDENTIAL**



B319114 Plate No. 4, HEAT No. LL-22104 2-3, Bhn Range 351/375. Front View. Detonated at -70°F.

G-12

**CONFIDENTIAL**

**CONFIDENTIAL**



B31912: Plate No. 18, HEAT No. 19026 3-B, Bhn Range 252. Rear View.  
Detonated at -30°F.

G-23

**CONFIDENTIAL**

**CONFIDENTIAL**



B31913: Plate No. 18, HEAT No. 19026 3-B, Bhn Range 202. Front View.  
Detonated at -30°F.

G-14

**CONFIDENTIAL**

**CONFIDENTIAL**

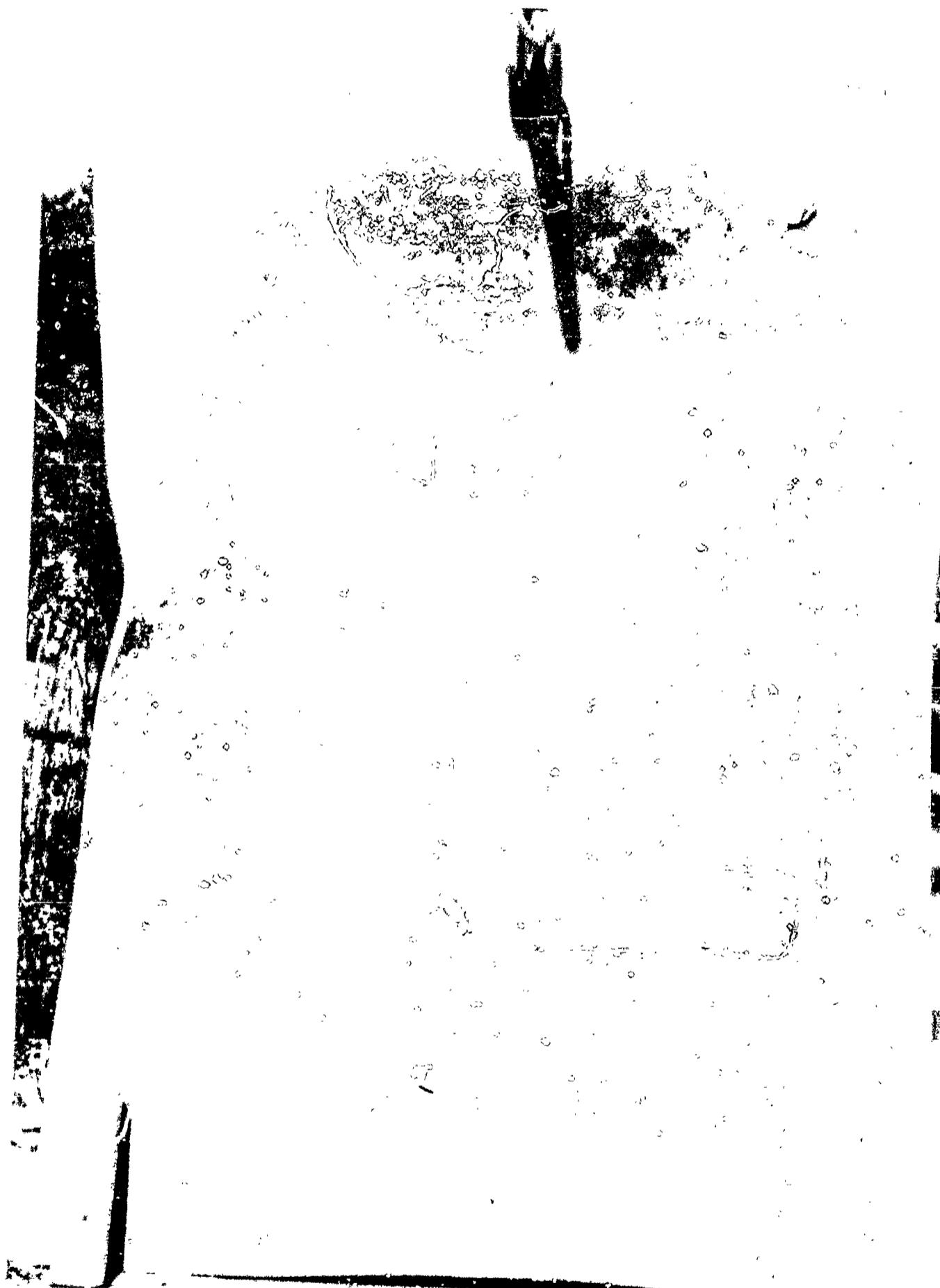


P31914: Plate No. 15, HEAT No. LL-22104 2-1, Bhn Range 241/255. Poor View. Detonated at -30°F.

G-14

**CONFIDENTIAL**

**CONFIDENTIAL**



331747: Plate No. 23, IEAT No. 19026 3-B, Ehn Range 252. Rear View.  
Photographed at -360°F.

G-10

**CONFIDENTIAL**

**CONFIDENTIAL**



E31840: Plate No. 1, HEAT No 10026 3-L, Bhn Range 2/2. Front View.  
Detonated at -30°F.

**CONFIDENTIAL**

**CONFIDENTIAL**



B31-A: Plate No. 22, HEAT No. 19026 3-B, Bnn Range 262. Rear View.  
Detonated at -10°F.

**CONFIDENTIAL**

**CONFIDENTIAL**



B31850: Plate No. 22, HEAT No. 10025 5-B, Ehn Zeng, P.M. Front View.  
Detonated at -20°F.

G- 1

**CONFIDENTIAL**

**CONFIDENTIAL**



B31951: Plate No. 20, HEAT No. 19025 3-B, Bnn Range 262. Rear View.  
Detonated at -10°F.

**CONFIDENTIAL**



B31852: Plate No. 20, HEAT No. 19026 3-B, Bhn Range '62. Front View.  
Detonated at -40° F.

G-31

**CONFIDENTIAL**

**CONFIDENTIAL**



B31853: Plate No. 13, HEAT No. LL-22104 2-2, Ehn Range 255/255. Front  
View. Detonated at -20°F.

**CONFIDENTIAL**



B31854: Plate No. 13, HWY No. LL-22104 2-2, Bhn Range 255/255. Rear View. Detonated at -20°F.

**CONFIDENTIAL**



B31855: Plate No. 12, HEAT No. LI-22104 2-2, Ehn Range 255/255. Front View. Detonated at -30°F.

G-34

**CONFIDENTIAL**

**CONFIDENTIAL**



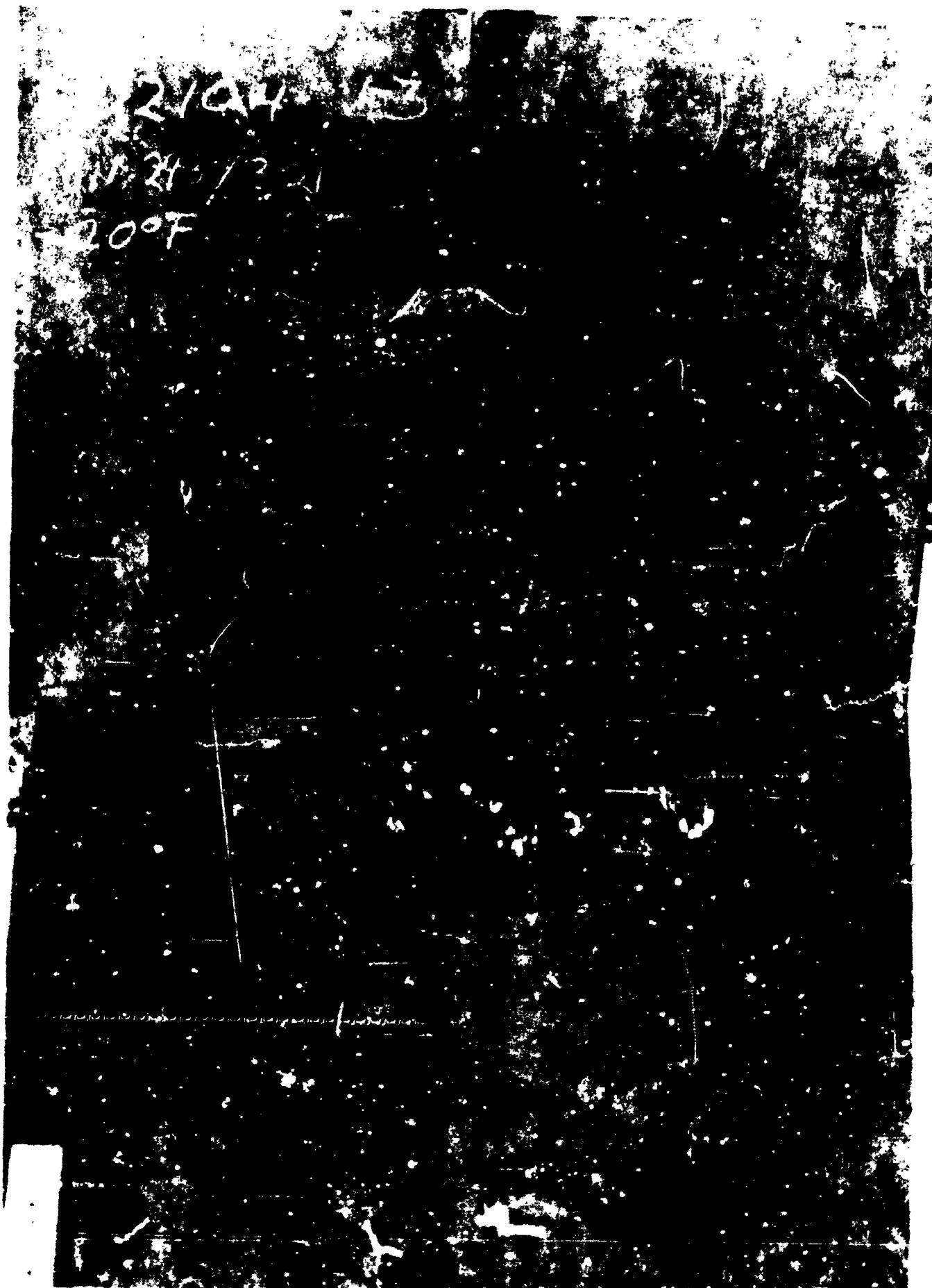
B31856: Plate No. 12, HEAT No. LL-22104 2-2, Ehn Range 255/255. Rear View. Detonated at -30°F.

**CONFIDENTIAL**



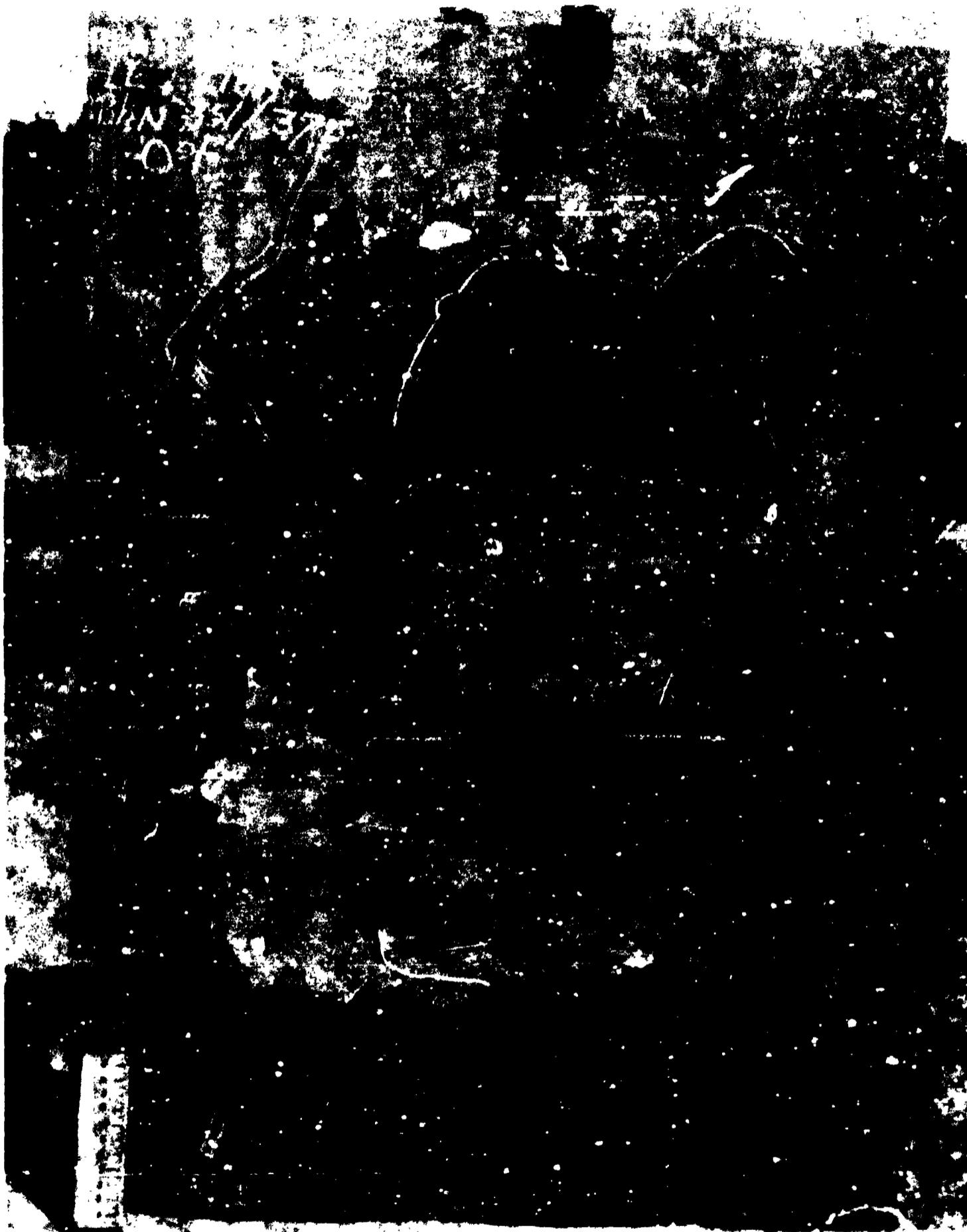
B31857: Plate No. 10, HEAT No. LL 22104 1-3, Bhn Range 293/321. Front View. Detonated at -20°F.

**CONFIDENTIAL**



E31858: Plate No. 10, HEAT No. LL-22104 1-3, Bhn Range 293/321. Rear View. Detonated at -20°F.

**CONFIDENTIAL**



B31859: Plate No. 6, HEAT No. LL-22104 2-3, Bhn Range 351/375. Front View. Detonated at 0°F.

**CONFIDENTIAL**



B31860: Plate No. 6, HEAT No. LL-22104 2-3, Bhn Range 351/375. Rear View. Detonated at 0°F.

**CONFIDENTIAL**



B31861: Plate No. 2, HEAT No. LL-22104 2-3, Btu Range 351/375. Rear View. Detonated at -30°F.

**CONFIDENTIAL**



B31862: Plate No. 2, HEAT No. LL-22104 2-3, Ehn Range 351/375. Front View. Detonated at -30°F.

G-42

**CONFIDENTIAL**